Chapter 5
Schedule of Maintenance Actions for Wells

5-1. Well and Plant Maintenance Schedule Overview

a. General. Chapter 9 provides a recommended maintenance program. This pamphlet provides recommendations and decision trees for a variety of operational settings. It is emphasized that this is a guide that should be adapted to local needs and should be revised as experience dictates.

b. Pre-selection of maintenance testing intervals and methods. There is considerable debate concerning appropriate monitoring and inspection intervals for maintenance of pumping and injection wells for HTRW sites. The purpose of such monitoring is to

Detect deterioration symptoms in time to permit the most cost-effective repair or replacement. Define the condition sufficiently so that correct rehabilitation diagnosis and treatment are possible.

The ideal situation from an operational standpoint is to achieve these objectives with the minimum possible intrusion, time, and material costs. Some biogeochemical environments and hydrologic conditions result in a reduced likelihood of well clogging and corrosion than others. Among those conditions so recognized are high-specific-capacity aquifer settings under nitrate-reducing conditions with modest total organic carbon. Clogging potential is greater at both higher and lower redox potentials (e.g., sulfate-reducing and iron-oxidizing). Field work on domestic water supply wells in a region with well clogging and water quality concerns documented in Cullimore and Legault (1997) showed that, if there is a background of data on well-deteriorating causes and effects, monitoring can be limited to one or a few biological parameters. These parameters can be supported by the hydrologic measurements previously identified in Chapter 2. However, defining deteriorating conditions is necessary during site development for monitoring to be safely minimized and can only be reasonably accomplished using existing wells in the area that have had time for biofouling to develop.

5-2. Minimum and Optimal Regular Schedule for First Year

This section and Sections 5-3 and 5-4 offer maintenance schedule recommendations based on the principle of establishing a data baseline and then settling into less frequent (or more intense) preventive maintenance (PM) activity if conditions warrant. Table 5-1 is a summary minimum recommendation for first-year maintenance activity frequency for an HTRW well array. It is an appropriate monitoring level-of-effort for a new (or newly started) facility if

- There is sufficient background information on the biogeochemical and hydrologic environment to make good estimates of the types and rates of deterioration to be expected.
- The well construction and system equipment are well documented (as in a new system) and not one taken over from another responsible party or O&M service provider).

a. Choosing level of effort. "Sufficient" information may include experience with other facilities with similar geochemistry and contaminants and hydrogeology or detailed site characterization including geochemical information from samples of existing (e.g., domestic water) wells from which conclusions about biological mechanisms can be made. Table 5-2 lists the type of data that should be available to permit a minimized first-year maintenance testing schedule (Table 5-1).

Table 5-1. Minimal First-Year PM Schedule

Maintenance Test	Testing Regime	Time Interval
Physical inspection	Borehole color video	On new wells, then at pump service intervals
	Surface facility inspection. Inspect and clean as needed at sampling points	Monthly or whenever visited
	Examination of pulled components	As needed, when pulled.
Hydraulic performance	Well discharge or acceptance (volume rate and pressure)	Weekly (recommend installation of automated data collection in accordance with CEGS 13405)*
	Drawdown or head change	Weekly (recommend installation of automated data collection)
	Graphical analysis	Quarterly
	Specific capacity test (well hydraulic performance) on selected representative wells.	Annually on selected trouble or recommended wells or at recommended shorter intervals
	Pump performance. Conduct step "pump" test (Section 2.1) of centrifugal pumps and similar wear analysis of positive displacement pumps, compare to "nominal" data.	At least annually or at recommended shorter intervals if pump service is severe (Q/s and pump test can be a single operation). Alternative: In maintenance system, include triggers for out-of-nomimal power readings.
Electrical (power)	System and motor V, A, ϕ, Ω	When visited for service (Recommend installation of current monitors with alarms)
Physicochemistry	PH, mV, and temperature	At well start up and quarterly using project onsite instruments (calibrated) or routine (laboratory)*
	Suspended particulate matter (sand, silt, clay)	At well testing then at pump test intervals
Biofouling microbial component	BART analyses. After clog-typing, pick suitable test type (IRB, SRB, or SLYM) and monitor for change.	At well start up for baseline, then quarterly on selected representative wells.
Treatments and service	Well hydraulic improvement and pumping systems	As testing indicates Q/s or injection rate drops below 90% or pumping system degrades
	Instrumentation calibration	In accordance with CEGS 13405
* CEGS 13405 specifies continuous metering, monitoring, and recording equipment for parameters such as flow, temperature, pressure, and physical-chemical properties of discharged fluids. It does not include methods for cleaning or other O&M issues.		

Table 5-2 Troubleshooting New Site Data Needs

Parameter	Potential Problems
Fe and Mn (total, Fe^{2+}/Fe^{3+}, Fe minerals, Mn^{4+}/Mn^{2+}, Mn minerals and complexes) sometimes other metals such as Al. Select based on presumed geochemistry.	Indications of clogging potential, presence of biofouling, Eh shifts. Fe transformations are the most common among redox-sensitive metals in the environment. Mn is less common but locally important.
S (total, S^{2-}/SO_4^{2-}, S minerals and complexes) as suspected due to site geochemistry.	Indications of corrosion and clogging potential, presence of biofouling, Eh shifts.
pH.	Indication of acidity/basicity and likelihood of corrosion and/or mineral encrustation. Combined with Eh to determine likely metallic mineral states present.
Conductivity.	Indication of TDS content and a component of corrosivity assessment.
Major ions.	Carbonate minerals, F, Ca, Mg, Na, Cl determine the types of encrusting minerals that may be present and are used in saturation indices. One surrogate for many cations is total hardness.
Sand/silt content (v/v, w/v).	Indication of success of development/redevelopment, potential for abrasion and clogging.
Biofouling parameters.	See Chapter 2 Section 9: Select appropriate methods to permit a complete but convenient assessment of biofouling mechanisms present.

b. Note on monitoring levels of effort. Choices should be made on the basis of long-term site life-cycle cost-effectiveness. The cost comparison should be between the cost to perform the appropriate maintenance vs. the cost of having the well system or the remediation project to fail to function properly with possible replacement of numerous wells. If specific experience with particular contaminant or site conditions permit a much reduced level of effort without impairing performance, this is acceptable. However, history indicates that

- Maintenance monitoring is cost-effective compared to the alternatives.
- Decisions made to minimize prevention and maintenance monitoring based on short-term experience may be regretted later as deteriorating phenomena result in performance degradation.

(1) It may actually reduce operational problems if certain monitoring is intensified, at least on certain critical wells. For example:

- Test pumps at least annually.
- Conduct graphical analyses of pumping tests monthly, instead of quarterly, for wells in which rapid decline or fluctuation of specific capacity is noted.
- Conduct physicochemical analyses at least monthly on wells which exhibit highly variable water quality.
- Add turbidity or (better yet) particle counting, using automated, in-stream sensors, to detect upswings in particulate sloughing that often accompanies enhanced biofouling.
- Add microscopy of samples from biofilm flow cells (Smith, 1992) to visually observe

changes in biofilm consistency, and analyze collected samples for changes in elemental analysis and crystalline structure of encrusting compounds. This information is useful in adjusting treatment programs.

(2) Rather than reducing monitoring, cost and labor savings can be realized by using automated sampling and data reporting and computerized maintenance management software to minimize human time investment. Automated systems should be evaluated periodically and verified manually.

5-3. Schedule for Reducing Maintenance After First Year

Maintenance (including monitoring) intervals can be reduced as trends are established. (Exception: troublesome wells that may be on annual or more-frequent treatment schedules based on first-year experience.) Typically, on wells performing adequately, the frequency of physicochemical and biofouling parameter testing can drop to quarterly if little change in conditions is noticeable after one year. Table 5-3 summarizes a post-first-year PM schedule.

5-4. Schedule for Intensive Maintenance for Critical Wells

a. Long-term intensive maintenance. As site experience develops (1 to 5 years), certain wells will be identified that will require intensive maintenance to continue useful operation. Intensive maintenance will include the following (detailed in Appendix C):

- Premaintenance testing of performance components.
- Removal of pump and inspection of components, repair and refurbish as needed.
- Chemical treatment (primary well and satellite wells).
- Mechanical development.
- Re-installation of well components.
- Testing (pre- and post-repair testing and PM testing, which includes parameters listed in Tables 5-1 and 5-2).

b. Schedule. A typical schedule is 3 to 6 months for injection wells and 6 months to annually for pumping wells. Where pump removal is determined not to be cost effective, or is especially difficult, pump testing to determine its status on the above schedule is a second option.

c. Well system modifications for treatment.

(1) In situations where pump removal is expensive and difficult (and this situation cannot be modified readily), some wells may respond well to in-well recirculating cleaning systems properly installed and operated. Such systems involve installing a return-flow pipe string to the open zone below the well pump, connected to the well pump discharge. An electronically actuated valve is controlled by a timer or other control device that flushes the sump or screen to remove built-up slime, oxides and sediment. Chemical feeds can be added to effect more aggressive cleaning.

(2) Additional wells should be installed at these locations to permit alternating wells in operation. Wells should be sufficiently far away from their alternating partners to be outside the likely clogging zones (if possible), but situated to maintain hydraulic control of the plume at this location.

(3) Satellite wells are recommended for introduction of cleaning solutions. Three to five wells may be installed at regular intervals around the pumping well at a distance of 2 to 7 m (6.6 to 23 ft). The distance depends on local hydraulic conductivity and the perceived degree of existing clogging).

Table 5-3. Long-Term PM Schedule

Maintenance Test	Testing Regime	Time Interval
Physical inspection	Borehole color video	At each major rehabilitation (before and after) or five years (whichever is sooner). Concentrate on screen and other stress points
	Surface facility inspection. Inspect and clean as needed at sampling points	Quarterly or each visit
	Examination of pulled components	As needed (at least test pump if not pulling it annually). Wells should be equipped for easy pulling if at all possible.
Hydraulic performance	Well discharge or acceptance (flow rate and pressure)	Weekly (recommend installation of automated data collection in accordance with CEGS 13405*)
	Drawdown	Weekly to biweekly. (recommend installation of automated data collection)
	Graphical analysis	Quarterly
	Specific capacity test (well hydraulic performance)	Annually or at recommended shorter intervals for specific representative or trouble wells.
	Pump performance. Conduct step "pump" test (Section 2-2) of centrifugal pumps and similar wear analysis of positive displacement pumps, compare to "nominal" data	At least annually or at recommended shorter intervals if pump service is severe (Q/s and pump test can be a single operation). Severe: This is subjective. One useful criterion: Pump replacement in 3 yr or less.
Electrical (power)	System and motor V, A, ϕ, Ω	Weekly (Recommend installation of current monitors with alarms)
Physicochemistry	Inorganic parameters	At least quarterly using project onsite instruments (calibrated) or routine monitoring (laboratory)*
	Suspended particulate matter (sand, silt, clay)	Manually at well testing then quarterly
	Turbidity (adds colloidal)	In-line monitors (continuous)*
Biofouling Microbial Component	BART analyses. Pick one indicator type based on past performance (IRB, SRB, SLYM, DN) and use for a marker.	Quarterly. Watch others (IRB, SRB, SLYM) at least annually. May be discontinued if results vary little over time.
	Biofilm flow cell for microscopy	Annually on selected wells
Treatments and Service	Well hydraulic improvement and pumping systems	As testing indicates Q/s drops below 90% or pumping system degrades
	Instrumentation calibration	In accordance with CEGS 13405.
* CEGS 13405 specifies continuous metering, monitoring, and recording of parameters such as flow, temperature, pressure, and physical-chemical properties of discharged fluids.		

(4) Chemical feeds (pellet or solution) are sometimes prescribed for well maintenance cleaning. Operators should resist any temptation to rely on chemical feed systems themselves to maintain wells. The feed suggested in item (1) would inject a cleaning solution along with flushing. Chemical choices recommended may be found in Section 6-1.